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Effect of Fatigue Life of Dissimilar Aluminium Alloy (AA 5083 – AA 6062) Joining by Friction Stir Welding

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ABSTRACT

The effect of processing parameters on the mechanical and microstructural properties of dissimilarAA5083–AA6062 joints produced by friction stir welding was analysed in this study. Different samples were produced by varying the advancing speeds of the tool as 5 mm/min and by varying the alloy positioned on the advancing side of the tool. In all the experiments the rotating speed is fixed at1200 RPM. All the welds were produced perpendicularly to the rolling direction for both the alloys. Microhardness (HV) and tensile tests performed at room temperature were used to evaluate the mechanical properties of the joints. For the mechanical fatigue tests, a resonant electromechanical testing machine was employed under constant loading control up to 10 Hz sine wave loading. The fatigue tests were conducted in the axial total stress–amplitude control mode, with R = rmin/rmax = -1. In order to analyse the microstructural evolution of the material, the welds' cross-sections a SEM observation was made of the fracture surfaces.

Keywords : Friction Stir Welding, ASTM, Fatigue

I. INTRODUCTION

Friction stir welding (FSW) is an innovative joining process, patented at The Welding Institute (TWI) in the 1991 [1]. Friction Stir Welding (FSW) has been commonly used to join materials of the same kind such as aluminum, copper, steel and more recently, titanium. However, FSW also has the potential to produce high-quality joints between dissimilar metals that usually differ in physical and mechanical properties[2]. When compared to traditional welding techniques, FSW strongly reduces the presence of distortions and residual stresses [3]. FSW uses a rotating (non-consumable) cylindrical tool that consists of a shoulder and a probe (Fig. 1). The shoulder is pressed against the surface of the materials being welded, while the probe is forced between the two components by a downward force. The rotation of the tool under this force generates a frictional heat that decreases the resistance to plastic deformation of the material. The softened material then easily moves behind the tool and forms a solid state weld as the stirred material is consolidated. FSW can be regarded as an autogenous keyhole joining technique [4]. The demand for use of lightweight structures in the transportation industries has increased attention in the use of light materials of Al and Mg alloys as structural materials due to the weight reduction of structures. Therefore, in order to incorporate Al alloy–steel hybrid structures, adequate joining process for dissimilar material combinations is required [5]. The FSW of relatively soft combinations of alloys (e.g., Al/Mg) is of particular interest in aerospace and automotive applications although hard combinations have not achieved commercial viability. Recently Murr has reviewed the FSW of a wide variety of dissimilar alloys and demonstrated that it is possible, on a laboratory scale, to friction stir weld aluminium metal matrix composites and other difficult materials not amenable to fusion processes. In many of these cases there are no alternatives available to friction stir welding [6]. However, fusion welding of Al and Mg alloys always produces coarse grains and large brittle intermetallic compounds in the weld metal. This situation suggests that fusion welding of Al and Mg alloys cannot be practically used [7]. It is well documented that many parameters, such as tool offsetting, rotation rate and traverse speed, influenced the weld properties of the dissimilar FSW joints [8-11]. The absence of melting in the friction stir welding (FSW) provides considerable tends to produce reliable dissimilar joints, and a few preliminary studies have been carried out to friction stir weld dissimilar aluminum alloys to other metals and some recent attempts have demonstrated a success in joining dissimilar metals and alloys using FSW, such as aluminum to steel and aluminum to magnesium[12]. In this study, the authors applied friction stir welding (FSW), which was developed by TWI [6], to weld dissimilar aluminum alloys AA 5083 to AA 6062.

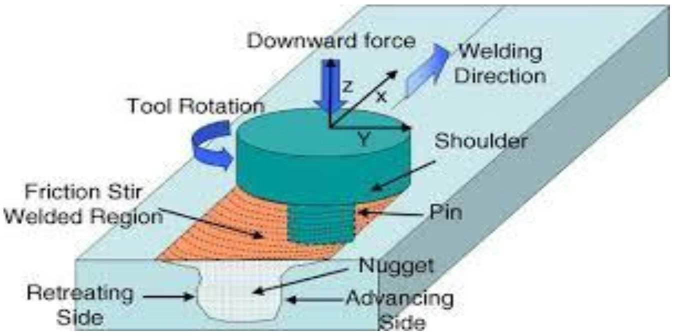

Fig. 1. A schematic illustration of friction stir welding butt-joint, the two sheets are transparently represented to show the probe.

II. EXPERIMENTAL PROCEDURE

The commercial AA 5083 and AA6062 aluminum alloys were friction stir welded on a setup was made on milling machine. The weld that was subjected to the detailed examination were selected after numerous welding experiments with constant welding parameters as well as the tool shape. The highest quality of the welds provided a background for the selection of process parameters and a type of the tool. Ultimately, the welding was performed with a hard steel 4340 tool with the shoulder diameter of 24 mm and the pin with length 5 mm. The process parameters were: welding velocity – mm/min, rotational speed – 1200 rpm. Al 5083 and Al 6062 material used for welding specimen. Al 5000 and 6000 series alloy used in Shipbuilding, Pressure vessels, Railroad cars, pipe and tubing, aircraft and automobile components.

Table 1. Chemical Composition of AA5083 and AA6063 aluminium alloy

AI alloy	Si	Fe	Cu	Mn	Mg	Ti	Cr	Zn	Al
AA5083	0.190	0.230	0.02	0.6	4.53	0.030	0.08	0.15	94.350
AA6062	0.420	0.160	0.001	0.001	0.53	0.013	0.00	0.00	98.875

III. METHODS AND MATERIAL

SETUP OF FRICTION STIR WELDING

Fig 2. Friction Stir Welding (FSW) Setup

Fig. 3. Tool used for FSW with 24mm shoulder diameter and 5mm pin length.

Fig .4. Plates of AA 5083 and AA 6062 before joining.

Fig 5. Plates of AA 5083 and AA 6062 after joining.

PREPARATION OF CT SPECIMEN

Preparation of specimen- (ASTM-E647 Standard) Specimen is prepared by cutting welded specimen on WEDM of dimension (55x53x6.1) mm, notch length of 11 mm from the loading line. CT specimen is used to find out the safe numbers of cycles in fatigue test. The total numbers of CT specimen were three.

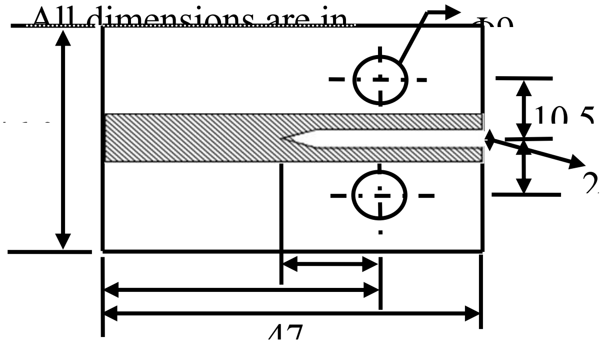

Fig 6. Dimensions of fatigue crack growth test CT specimen.

Fig 7. Fatigue growth test CT specimen.

Fatigue test

Fatigue test is carried out on fatigue testing machine with a loading of ± 2.5 KN, Frequency 10 Hz Stress ratio(R) -1. All specimens tested were firstly pre cracked in fatigue, using load control and a sinusoidal waveform (R= -1), in order to allow a short fatigue crack to nucleate from the machined V-notch root (starter notch) and propagate beyond the plastic zone induced during machining of specimen. The crack initiation and propagation was carefully controlled on the front and back surfaces of the specimen using hot and cold lights, together with a magnifying glass (x30) connected to a measuring device and a Veho® USB camera linked to the computer, which enable to acquire screenshots, videos and to measure the crack with the help of an appropriate software . The length of the fatigue pre crack extension varied from 8 to 13 mm, for welded specimen and number of cycles varying between about 600 and 30,000 cycles. FCGR tests followed procedure and recommendations given in standard ASTM E647.

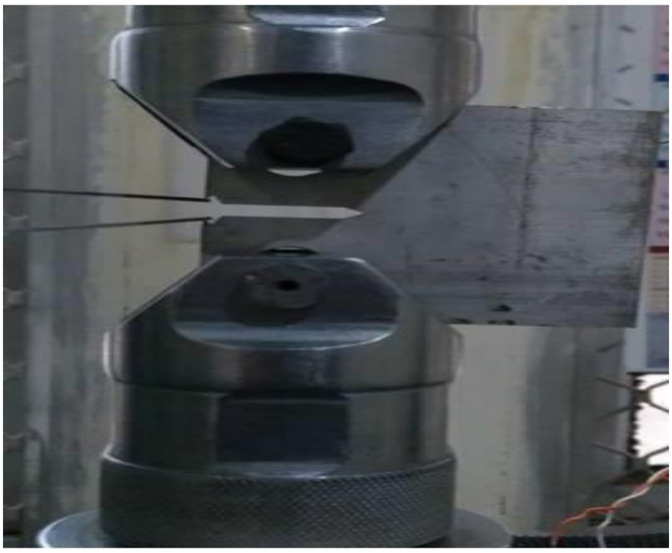

Fig. 8. – CT Specimen griped on fatigue testing machine

Fig 9. Fractured CT specimens after fatigue test.

Testing condition For fatigue crack propagation at constant amplitude Machine Used – Fatigue testing machine Plug 'N' play (±2.5 KN) at room temperature Control – Load mode, Crack length-COD gauge Frequency 10 Hz, Stress ratio -1, Stress levels- 20-50 % of fatigue strength.

IV. RESULTS AND DISCUSSION

Fatigue damage of mode 1 for CT specimen under block loading condition fig. shows the relation between crack length and no. of cycles. The length of the fatigue pre crack extension varied from 8 to 13 mm, for CT specimen and number of cycles varying between about 600 and 30,000 cycles. As shown in fig. the safe numbers of cycles for CT specimen are 30,000 for crack length of 13 mm. with a loading of ±2.5 KN.

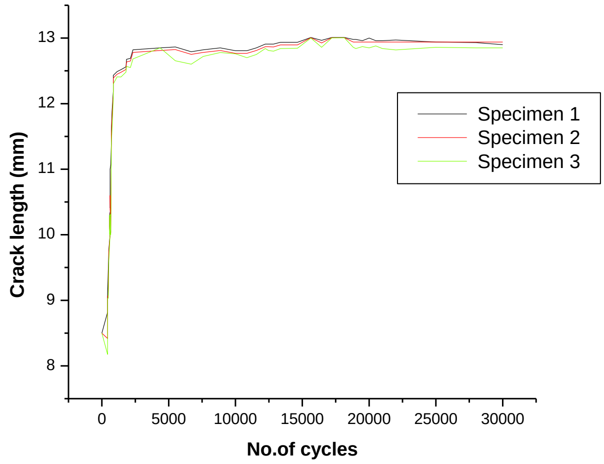

Fig 10. - Crack length vs No. of cycles (N) for welded CT specimen

Now we are compare the fatigue life cycle of FSW welded CT specimen from the CT specimen of AA 5083 and 6062. Fatigue testing of AA 5083 and AA 6062 done at same parameters. To compare the fatigue life of AA 5083, AA 6062 and welded specimen a graph is plotted between crack length and number of cycles (N).

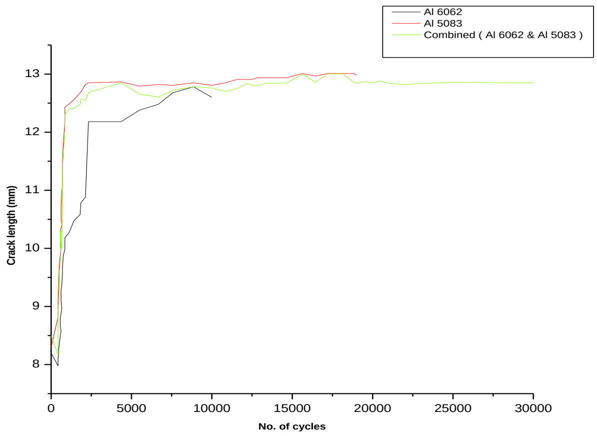

Fig 11. Comparison of all three graph Crack length vs No. of cycles (N)

Table 2. Comparison of fatigue life

Alloy	Fmax.	Fmin.	R	Frequency	a	No. of cycle
AA 6062	+2.5 kN	-2.5 kN	-1	10 Hz	7.68	10000
AA 5083	+2.5 kN	-2.5 kN	-1	10 Hz	7.68	20000
AA (6062 +5083)	+2.5 kN	-2.5 kN	-1	10 Hz	7.68	30000

A deep analysis of the fatigue behavior of two different Al alloys AA 5083, AA 6062 and combined (AA 6062 & AA5083) fatigue test is carried out to find out the safe numbers of cycles .The result shows in fig.10 after comprising with fig.10 the safe numbers of cycles for AA5083 are 20,000, for AA 6062 are 10,000 and for combined (AA 6062 & AA5083) are 30,000 .Which indicates fatigue life of combined (AA 6062 & AA5083) is higher than from AA 5083 and AA 6062 at same loading condition ± 2.5 KN.

V. CONCLUSION

A research work regarding fatigue crack propagation under opening-modes I, for FSW combined (AA 6062 & AA 5083), AA 6062 and AA 5083 was developed and remarks could be drawn that fatigue life of combined (AA 6062 & AA 5083) is 30,000 cycles, AA 5083 is 20,000 cycles and the fatigue life of AA 6062 is 10,000 which indicates fatigue life of combined (AA 6062 & AA 5083) is higher than the fatigue life of AA 6062 and AA 5083 at same loading condition ±2.5 KN.

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